No 40.

(*NEW SERIES*)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY EPARTMENTS

OF THE

GOVERNMENT OF INDIA

THE DESTRUCTION OF FLEAS BY EXPOSURE TO THE SUN.

BY

CAPTAIN J. CUNNINGHAM, M.D., I.M.S.

Offg. Assistant to the Director, Bombay Bacteriological Laboratory

---

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT OF INDIA.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1911

Price annas 8 or 9d.

No. 40.

(NEW SERIES)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS

OF THE

GOVERNMENT OF INDIA

THE DESTRUCTION OF FLEAS BY EXPOSURE TO THE SUN.

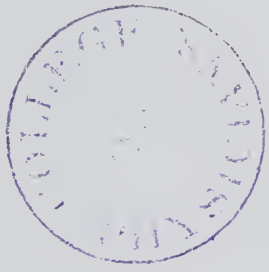
BY

CAPTAIN J. CUNNINGHAM, M.D., I.M.S.

Offg. Assistant to the Director, Bombay Bacteriological Laboratory

---

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA



CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1911

Agents for the Sale of Books published by the Superintendent of Government Printing, India, Calcutta.

In England.

Mr. E. A. Arnold, 41 and 43, Maddox Street, Bond Street, London, W.

Messrs. Constable & Co., 10, Orange Street, Leicester Square, W.C.

Messrs. Kegan Paul, Trench, Trübner & Co., 43, Gerrard Street, Soho, London, W.

Mr. Bernard Quaritch, 11, Grafton Street, New Bond Street, W.

Messrs. P. S. King & Son, 2 and 4, Great Smith Street, Westminster.

Messrs. H. S. King & Co., 65, Cornhill, and 9, Pall Mall, London.

Messrs. Grindlay & Co., 54, Parliament Street, London, S.W.

Mr. T. Fisher Unwin, 1, Adelphi Terrace, London, W.C.

Messrs. W. Thacker & Co., 2, Creed Lane, London, E.C.

Mr. B. H. Blackwell, 50 and 51, Broad Street, Oxford.

Messrs. Deighton Bell & Co., Cambridge.

Messrs. Luzac & Co., 46, Great Russell Street, London, W.C.

On the Continent.

Mr. Rudolf Haupt, 1, Dorrienstrasse, Leipzig, Germany.

Mr. Otto Harrassowitz, Mr. Karl Hiersemann } Leipzig.

Messrs. R. Friedlander & Sohn, Berlin W. N., Carlstrasse, 11.

Mr. Ernest Leroux, 28, Rue Bonaparte, Paris.

Mr. Martinus Nijhoff, The Hague, Holland.

In India.

Messrs. Thacker, Spink & Co., Calcutta and Simla.

Messrs. Newman & Co., Calcutta.

Messrs. R. Cambray & Co., Calcutta.

Messrs. S. K. Lahiri & Co., Calcutta.

Messrs. B. Banerjee & Co., Calcutta.

Messrs. Higginbotham & Co., Madras.

Messrs. V. Kalyanarama Iyer & Co., Madras.

Messrs. G. A. Natesan & Co., Madras.

Messrs. S. Murthy & Co., Madras.

Messrs. Thompson & Co., Madras.

Messrs. Temple & Co., Madras.

Messrs. Combridge & Co., Madras.

Messrs. P. R. Rama Iyer & Co., Madras.

Messrs. A. R. Pillai & Co., Trivandrum.

Messrs. Thacker & Co., Ld., Bombay.

Messrs. A. J. Combridge & Co., Bombay.

Messrs. D. B. Taraporevala, Sons & Co., Bombay.

Mrs. Radhabai Atmaram Sagoon, Bombay.

Mr. Sunder Pandurang, Bombay.

Messrs. Gopal Narayan & Co., Bombay.

Superintendent, American Baptist Mission Press, Rangoon.

Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore and Calcutta.

Mr. N. B. Mathur, Superintendent, Nazair Kanun Hind Press, Allahabad.

Messrs. A. Chand & Co., Punjab.

Messrs. A. M. & J. Ferguson, Ceylon.

Babu S. C. Talukdar, Proprietor, Students and Company, Cooch Behar.

List of numbers of Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India (New Series) published previous to the present issue.

No. 1. Standardisation of Calmette's Anti-Venomous Serum with Pure Cobra Venom: the Deterioration of this Serum through keeping in India, by *Captain G. Lamb, I.M.S., and Wm. Hanna, Esq., M.B.* Price As. 3 or 4*d.*

No. 2. Malaria in India, by *Captain S. P. James, I.M.S.* Price Re. 1-8 or 2*s.* 3*d.*

No. 3. Some Observations on the Poison of Russell's Viper (Daboia Russellii), by *Captain G. Lamb, I.M.S., and Wm. Hanna, Esq., M.B.* Price As. 5 or 6*d.*

No. 4. On the Action of the Venoms of the Cobra and of the Daboia on the Red Blood corpuscles and on the blood plasma, by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 5. Specificity of Anti-Venomous Sera, by *Captain G. Lamb, I.M.S.* Price As. 3 or 4*d.*

No. 6. First Report on the Anti-Malarial Operations in Mian Mir, 1901—03, by *Captain S. P. James, I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 7. Some Observations on the Poison of the Banded Krait (Bungarus Fasciatus), by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 8. A Preliminary Report on a Parasite found in Patients suffering from Enlargement of the Spleen in India, by *Lieutenant S. R. Christophers, I.M.S.* Price Re. 1-8 or 2*s.* 3*d.*

No. 9. Second Report of the Anti-Malarial Operations at Mian Mir, 1901—03, by *Lieutenant S. R. Christophers, I.M.S.* Price As. 10 or 1*s.*

No. 10. Specificity of Anti-Venomous Sera (Second Communication), by *Captain G. Lamb, I.M.S.* Price As. 8 or 9*d.*

No. 11. On a Parasite found in persons suffering from Enlargement of the Spleen in India—Second Report, by *Lieutenant S. R. Christophers, I.M.S.* Price Rs. 2 or 3*s.*

No. 12. On the Morphology, Teratology, and Diclinism of the Flowers of Cannabis, by *Major D. Prain, I.M.S.* Price As. 14 or 1*s.* 4*d.*

No. 13. Oriental or Delhi Sore, by *Captain S. P. James, I.M.S.* Price As. 10 or 1*s.*

No. 14. On a Parasite found in the White Corpuscles of the Blood of Dogs, by *Captain S. P. James, I.M.S.* Price As. 10 or 1*s.*

No. 15. On a Parasite found in persons suffering from Enlargement of the Spleen in India—Third Report, by *Lieutenant S. R. Christophers, I.M.S.* Price As. 10 or 1*s.*

No. 16. The Specificity of Anti-Venomous Sera with special reference to a Serum prepared with the Venom of the Daboia Russellii, by *Captain G. Lamb, I.M.S.* Price As. 6 or 7*d.*

No. 17. Snake-Venoms in relation to Hæmolysis, by *Captain G. Lamb, I.M.S.* Price As. 6 or 7*d.*

No. 18. Hæmogregarina Gerbilli, by *Lieutenant S. R. Christophers, M.B., I.M.S.* Price As. 10 or 1*s.*

No. 19. On Kala Azar, Malaria and Malarial Cachexia, by *Captain S. P. James, M.B., I.M.S.* Price Re. 1-4 or 1*s.* 11*d.*

No. 20. Serum-Therapy of Plague in India; Reports by Mr. W. M. Haffkine, C.I.E., and various Officers of the Plague Research Laboratory, Bombay, by *Lieutenant-Colonel W. B. Bannerman, M.D., B.Sc., F.R.C.S., I.M.S.* Price As. 14 or 1*s.* 4*d.*

No. 21. On the Standardisation of Anti-Typhoid Vaccine, by *Captain George Lamb, M.D., I.M.S.* (*Director, Pasteur Institute of India*), and *Captain W. B. C. Forster, M.B., D.P.H., I.M.S.* Price As. 6 or 7*d.*

No. 22. Mediterranean Fever in India: Isolation of the Micrococcus Melitensis, by *Captain George Lamb, M.D., I.M.S.*, and *Assistant Surgeon M. Kesava Pai, M.B., C.M.* (*Madras*). Price As. 10 or 1*s.*

No. 23. The Anatomy and Histology of Ticks, by *Captain S. R. Christophers, M.B., I.M.S.* Price Rs. 3 or 4*s.* 6*d.*

No. 24. On a Parasite found in the White Corpuscles of the blood of Palm Squirrels, by *Captain W. S. Patton, M.B., I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 25. On the importance of Larval Characters in the Classification of Mosquitoes, by *Captain S. R. Christophers, M.B., I.M.S.* Price As. 8 or 9*d.*

No. 26. Leucocytozoon Canis, by *Captain S. R. Christophers, M.B., I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 27. Preliminary Report on the Development of the Leishman-Donovan Body in the Bed Bug, by *Captain W. S. Patton, M.B., I.M.S.* Price As. 8 or 9*d.*

No. 28. The Sexual Cycle of Leucocytozoon Canis in the Tick, by *Captain S. R. Christophers, M.B., I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 29. Piroplasma Canis and its Cycle in the Tick, by *Captain S. R. Christophers, M.B., I.M.S.* Price Rs. 2 or 3*s.*

No. 30. The Theory and Practice of Anti-Rabic Immunisation, by *Captain W. F. Harvey, M.B., I.M.S.*, and *Captain Anderson McKendrick, M.B., I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 31. The Development of the Leishman-Donovan Parasite in Cimex Rotundatus—Second Report, by *Captain W. S. Patton, M.B., I.M.S.* Price Re. 1 or 1*s.* 6*d.*

No. 32. An Enquiry on Enteric Fever in India carried out at the Central Research Institute, Kasauli, under the direction of Lieutenant-Colonel D. Semple, M.D., and Captain E. D. W. Greig, M.D. Price Re. 1-2 or 1*s.* 9*d.*

No. 33. The Production of Alkali in Liquid Media by the Bacillus Pestis, by *Lieutenant-Colonel W. B. Bannerman, M.D., B.Sc., I.M.S.* Price As. 5 or 6*d.*

No. 34. Standards of the Constituents of the Urine and Blood and the bearing of the Metabolism of Bengalis on the Problems of Nutrition, by *Captain D. McCay, M.B., I.M.S.* Price As. 12 or 1*s.* 2*d.*

No. 35. Black-water Fever, by *Captain S. R. Christophers, M.B., I.M.S.*, and *Dr. C. A. Bentley.*

No. 36. Observations on Rabies: with special reference to an Atrophic form of the disease occurring in animals, by *Major G. Lamb, M.D., I.M.S.*, and *Captain A. G. McKendrick, M.B., I.M.S.* Price As. 8 or 9*d.*

No. 37. Investigations on Bengal Jail Dietaries with some Observations on the Influence of Dietary on the Physical Development and Well-being of the People of Bengal, by *Captain D. McCay, M.B., B.Ch., B.A.O., I.M.S.* Price As. 8 or 9*d.*

No. 38. Preliminary Report on the Killing of Rats and Rat Fleas by Hydrocyanic Acid Gas, by *Captain W. D. H. Stevenson, M.B., I.M.S.* Price As. 8 or 9*d.*

No. 39. The Applicability to Medico-Legal Practice in India of the biochemical tests for the origin of blood-stains, by *Lieutenant-Colonel W. D. Sutherland, M.D., I.M.S.*

Published by and on sale at the Office of the Superintendent of Government Printing, India, Calcutta. Copies are also available from all Agents for the sale of Government publications

THE DESTRUCTION OF FLEAS BY EXPOSURE TO THE SUN.

INTRODUCTORY.

THERE can be no doubt that plague is frequently carried from one locality to another by means of clothing and baggage which contain infected fleas, and it follows that any means by which such clothing can be rendered rapidly and effectually flea-free will be of considerable value in preventing the spread of the disease.

There is unfortunately considerable difficulty in obtaining an insecticide thoroughly suited to this purpose.

Plague is now so universal in India that the disinfection of the clothing of new arrivals should be carried out as a routine measure in every small town and village. This, however, would entail an amount of work which would be altogether impracticable unless it were carried out by the people themselves.

A means of disinfection is, therefore, required which is of a simple and harmless nature, and can be used in all parts of the country without causing much expenditure. It is safe to say that no efficient disinfectant has yet been discovered which combines all these necessary qualifications.

In India, however, where the seasons are regular and where there is continuous sunshine for the greater part of the year, the sun has been employed as an agent in this matter.

Exact experiments to test the value of the sun as an agent by means of which "soiled clothing" could be freed from fleas were first initiated by Lieut.-Colonel Bannerman, I.M.S., and in the report of the Bombay Bacteriological Laboratory for the year 1907 the results of the experiments carried out under his dirction were detailed. These experiments showed that an exposure of three hours is sufficient to remove all the fleas from infested rags.

As these first experiments were undertaken to see if rags intended for export could in this way be rendered safe the ultimate fate of the fleas was not at that time investigated, and it was thought that these might survive by sheltering under grass and leaves.

The Government of India having subsequently (Home Department Notification No. 1822, dated 10th August 1908) removed the restriction against the export of rags, etc., from infected localities, further experiments were not made. The subject was again taken up when, as a result of the work of the Plague Commission, it became clear that there was real danger of importation of plague by fleas in travellers' clothes or baggage. It then became important

to find out some cheap and simple method of ridding these articles of fleas and, at the suggestion of Colonel Bamber, I.M.S., then acting Sanitary Commissioner with the Government of India, various reputed powders were tried. Of these, the only one at all successful was Naphthaline powder, but this acted very slowly requiring $6\frac{1}{2}$ hours to kill fleas in a closed space and 9 hours in the open air (*vide* Annual Report of the Bombay Bacteriological Laboratory for 1909). It was, therefore, out of the question as a pulicide for use by villagers, who would require something cheap and of speedy action.

It was then that, on the suggestion of Colonel Bannerman, I.M.S., the 1907 experiments were repeated and extended, as detailed in the following report.

Before passing on to a description of these experiments, however, it will be necessary to enquire into the various factors which influence the power of the sun, because any changes of this kind which occur must necessarily alter its value as an insecticide. Sunlight and heat are generally believed to be the chief agents in the natural disinfection which is continually being carried on, and we may assume for the present that these two factors are responsible for the sun's action on flea-infested clothing.

Now the amount of light and heat which reach the earth are not always the same, but are liable to changes, which are due to differences of geographical position, the season of the year and also certain atmospheric conditions.

As a rule the light is not affected to the same extent as the temperature, in fact there may be actually no change in the former, while the difference in the latter is very considerable.

For instance, if we examine the changes which are due to geographical position, we find that the amount of light in different parts of India is more or less constant, while the temperature varies very considerably according to the latitude.

The changes which are due to the season of the year and time of day require no explanation. Everyone knows that the sun is more powerful in the hot than the cold weather and that the hours about noon are as a rule hotter and brighter than any other part of the day. These changes are fairly constant from year to year and day to day.

Lastly, the changes which are due to atmospheric conditions remain to be considered. The most common cause of these in India is the wind, which is capable of altering the temperature of the ground according to changes in its direction and velocity. At certain times of the year too, small clouds which pass over the sun without actually producing rain diminish to a certain extent the amount of light and heat which reach the earth.

These changes are not very great throughout the greater part of the year but they are extremely irregular because the atmospheric conditions which produce them are hardly ever the same for any length of time. It is clear, therefore, that the power of the sun is constantly varying within certain limits, and it is necessary that the conditions which produce these changes should be considered and carefully recorded in any experiments which are carried out to test the value of the sun as a disinfectant. The experiments which were performed with this object consisted in exposing flea-infested clothing to the sun under different conditions. They were carried out in the grounds of the Bombay Bacteriological Laboratory between the months of December and June. This period of the year in Bombay corresponds to the latter half of the cold and the whole of the hot weather. The sun was, therefore, gradually increasing in power during the greater part of the time that the experiments were proceeding. The total change of power which occurred in this way, however, was not so great as it would have been in some other parts of the country.

The time of day at which the exposures were made depended upon the strength of sun required. The experiments which tested its full power were carried out about midday, but when lower temperatures were required the exposures were made earlier in the morning. The presence of any wind or clouds was also noted, but in the majority of experiments these conditions did not affect the results to any appreciable extent.

The experiments were carried out :—

(1) In large tin trays, specially designed, so that the movements of the fleas could be watched throughout the experiment.

(2) On a piece of ground which was prepared after experience gained in the tray experiments.

The trays were made from sheets of tin rivetted together; they measured 4 feet broad by 4 feet 6 inches long. Their sides were 4 inches high and stood at right angles to the bottom. The upper borders of these were turned over on themselves towards the centre of the tray so as to prevent the escape of any fleas which succeeded in jumping to the top of the sides. The floor was covered with linoleum which was coloured so as to imitate the ground as closely as possible. Any crevices or cracks which existed between the tin and the linoleum were filled up with putty so as to prevent them being used by the fleas as a shelter against the sun. The covering of linoleum was necessary owing to the uncovered tin becoming so hot when exposed to the sun, that the fleas were scorched and died almost instantly when placed on it.

The description of the piece of ground used for the second series of experiments will be better understood if it is given immediately before the account of

the experiments themselves. The fleas used for the experiments were rat-fleas, which had been removed a short time previously from Bombay rats. A large number of these rats are brought to the laboratory daily throughout the year, so that the vitality of the fleas was assured.

Dhurries (cotton carpets) were used in the majority of cases to represent the native clothing. These were selected because they are thicker and more closely woven than any other kind of material found in native baggage, and for this reason would be more likely to resist the rays of the sun. While the experiments were in progress, it was suggested that padded clothing, such as *resais* (bed quilts) and quilted coats, might also require disinfection, so that certain of the experiments were repeated to test the action of the sun on this type of clothing also.

An indication of the power of the sun was obtained by taking the temperature on the upper and under surfaces of the clothing. The thermometers were watched carefully during the experiments, and in those cases in which the temperature throughout the exposure remained within certain limits the reading which was made at the end of the experiments was the only one recorded. In some of the later experiments, which were carried out a short time before the monsoon arrived, the sun was repeatedly overclouded during each exposure, and a more complete record of the variations in temperature had therefore to be kept. All the readings have been made according to the Fahrenheit scale.

The report has, for convenience, been divided into four parts. The first of these deals with the action of the sun on fleas in clothing, and the fate of these insects when they have left the clothes. The second describes the experiments undertaken to devise a method by means of which the sun can be used to the best advantage as a disinfectant for flea-infested clothing. The third deals with the experiments which were carried out with the resais. Lastly, an account of certain experiments which were performed with a view to designing a simple form of thermometer, has been added as an appendix.

Part I.

The action of the sun on fleas and the fate of the fleas when exposed to it.

In the experiments published in the Bombay Bacteriological Laboratory report for 1907, it was shown that rags if spread on the ground in thin layers were freed from fleas in three hours. In these experiments, however, the kind of ground upon which the rags were spread was not regarded as of any consequence. This is an important point, because the fleas on leaving the clothes must jump on to the ground, and their fate will therefore depend upon the amount of shelter they can find there.

In the following experiments the question has been treated from this point of view and observations have been made upon the different ways in which fleas behave when the clothes are spread out on different kinds of ground. These experiments were carried out on trays, and in the first of these (Ex. I, page 17) the clothes were spread on the floor of the tray alone, which had been made to represent a hard piece of ground with a smooth surface. In the second series (Ex. II, page 18) the floor was covered in the one case with sand, and in the other with grass and leaves, to test the behaviour of the fleas when the clothes were spread on these two kinds of ground.

The procedure was briefly as follows :—

A piece of ground was selected in the most sunny part of the compound, and a sun shelter roofed with asbestos sheets was erected over it. Both the control and experimental trays were placed side by side beneath this while the experiment was being prepared. The dhurries were first spread upon the floors of the trays, and the same number of fleas were put on each, half the total number being placed below and half above each dhurrie. The thermometers were then placed in position (in the first experiment, however, the temperatures were not taken). After a sufficient time had elapsed to allow the fleas to become accustomed to their new surroundings the experimental tray was drawn out into the sun, the control tray being left under the shelter. While the experimental tray was in the sun the behaviour of the fleas in it was very carefully watched, and when the time of exposure had elapsed the final reading of the thermometers in both trays was noted and the tray was pushed back under shelter again. The dhurries were then shaken up and four guineapigs were placed in each tray to capture any fleas which were still alive. At the end of three hours these guineapigs were lightly chloroformed and searched for fleas, and the total number found on them was recorded. In experiment I (page 17) the experimental tray was kept in the sun for varying

lengths of time so as to find out the exposure which had the strongest effect on the fleas. In experiment II (page 18) the exposure which had been previously found to be most suitable was employed throughout.

As soon as the experimental tray was drawn into the sun the fleas could be seen moving off the upper surface of the dhurrie. In trying to escape the glare they turned their heads away from the sun and travelled towards the side of the tray which faced them. As the floor of the tray grew hotter, the fleas, which had by this time arrived at the side, began to die, and at the end of seven minutes none of these remained alive.

A reference to Table I (page 17), however, will show that this exposure was not nearly long enough to kill the fleas which were on the under surface of the dhurrie, and it was found that the tray had to be left in the sun for 45 minutes before all the fleas in it were killed.

The majority of the fleas underneath the dhurrie did not try to escape, but were found dead on the floor of the tray when the dhurrie was raised.

The results which were obtained by spreading the clothes on sand (Table II, Nos. 1 and 2, page 18) were much more marked.

The surface of the sand appeared to absorb the heat of the sun faster than the hard surface of the tray, and for this reason any fleas which jumped off the dhurrie were almost immediately killed. At the end of the experiment, too, dead fleas could be seen lying on the sand when the dhurrie was lifted up, and no fleas were to be found on any of the guineapigs. The fleas were carefully watched to see if they made any attempt to burrow into the sand to escape the glare and heat, but they showed no inclination to do so at any time. In fact as soon as they reached the sand, it appeared as if their chief object was to jump off it again as soon as possible.

In the experiments in which the dhurries were spread on leaves and grass (Table II, Nos. 3, 4 and 5, page 18) the results were not so satisfactory. Those fleas which could be watched certainly left the clothes as soon as they were exposed, but they immediately dived under the grass and so obtained ample protection from the sun. This was proved by the fact that at the end of 45 minutes exposure many of them were recovered on the guineapigs, which had been put in the tray at the end of the experiment. The fate of the fleas beneath the clothing appears to depend on the amount of heat which is developed on the ground underneath the clothes. When the temperatures are high (Table II, Nos. 1, 2, 3 and 4, page 18) all the fleas are destroyed, but when it is comparatively low (as in No. 5) a large number of them are able to escape. This appears to show that *the heat* of the sun is the factor which causes the destruction of the fleas. The high temperature which is obtained underneath the clothes spread on sand is probably due to the fact that the clothes are in

close apposition to the ground, and the sand is therefore able to absorb the heat without much difficulty. When lying on grass, however, the clothes are never in close contact with the ground but are separated from it by a space through which the air can circulate and which therefore prevents the heat reaching the surface of the ground.*

The conclusions which have been obtained from these experiments may be briefly summed up as follows:—

(*i*) The pulicidal power of the sun appears to be chiefly due to the amount of heat which it gives off.

(*ii*) The fate of the fleas, which escape from clothes exposed to the sun, depends on the nature of the ground upon which the clothes are spread. On hard ground, and more especially on sand, the fleas are all destroyed; on grass they will in all probability be able to find shelter and therefore escape.

(*iii*) The time of exposure necessary to destroy all the fleas is about 45 minutes when the clothes are spread on hard ground, and is probably somewhat less when sand is employed.

---

* This has been corroborated by observations made in various parts of the Laboratory compound. The temperature of the ground under the grass is seldom above 95° when the thermometer reading in the sun is 130° or over.

Part II.

Experiments carried out to discover the most practical method of using the sun as a pulicidal agent for flea-infested clothing.

The conclusions in the previous section show that clothes can be readily freed from fleas by spreading them out on a flat surface covered with a layer of sand which is exposed to the sun.

The practical value of this method of disinfection, however, will entirely depend, firstly, upon the number of hours per diem the sun will be able to yield a sufficient amount of heat to destroy the fleas within a reasonable length of time; and, secondly, upon the area of ground which will have to be covered with sand to prevent the escape of any of these insects.

It has already been shown that clothes require to be exposed to the sun for 45 minutes to kill all the fleas, and it must be acknowledged that this period is well within the limits of "a reasonable length of time."

If, therefore, the smallest amount of heat which is necessary to destroy the fleas in 45 minutes is discovered, it will be easy to calculate the probable number of hours per diem during which this method of disinfection can be employed.

The experiments which have been performed with this object were carried out in the trays, and their technique is precisely the same as that of the experiments performed in the previous section. The differences in temperature were obtained by making the exposures at various times of the day, and although it was obviously impossible to arrange that each successive degree of heat should be tested, a good series of temperatures has been obtained.

The results are shown in Table III (page 19). The experiments have been arranged in order according to the temperature found to be present on top of the carpet. No attention has been paid to the date or time of day at which the exposure was made. With a few exceptions, however, it will be seen that the low temperatures were obtained early in the morning, and the higher ones later on in the day. The time of exposure in the experiments carried out earlier in the year, was 45 minutes, in the later ones this was extended to one hour to allow for experimental error. A glance at the table (Table III, page 19) will show that the temperatures between 95° and 112° are not strong enough to destroy all the fleas, although there is a great diminution in their numbers in the two last experiments which registered 112°. From 116° upwards all the fleas were killed. The minimum temperature, therefore, lies between 112° and 116°,—probably 116° itself, because in two experiments which were carried out by gradually heating a test-tube containing fleas by immersion in warm water, it was found that the exact temperature at which

they were killed was 116·4° on the first occasion and 118·4° on the second. If we add 4° to this result, which has been obtained experimentally, and call the minimum 120°, we may be certain of obtaining a temperature which will be fatal under the most practical conditions.

The results obtained by recording the temperatures under the carpet are also interesting. In the first place, it will be seen that they follow the increase of the temperatures in the sun fairly closely. Between 91° and 118° they are somewhat lower than the corresponding temperatures above the carpet, but above this—with only one exception—they are always one or two degrees higher than the temperature recorded on the upper surface.

The time of day at which the temperature on a sandy surface will reach 120° in the sun will vary according to the place and season of the year, and this would have to be found for each district. In Bombay most of the experiments show that this temperature was reached between 9 A.M. and 10 A.M., and remained until about 6 P.M.

The area of ground which will have to be covered with sand to prevent the escape of any fleas will depend upon the distance the fleas are able to travel on the sand before they are destroyed. This applies to the fleas on only the upper surface of the clothes, those underneath do not concern us here because it has already been shown that they remain under the clothes.

The experiments which have been performed to demonstrate this have been carried out in a "flea park" which was prepared in the following way:—

A sunny piece of ground measuring about 16 feet square was cleared of grass and rubbish, and its surface was rendered quite smooth by scrubbing it with bricks to get rid of the roots of grass. It was then well watered and rolled and finally cow-dunged. After this a 3-inch layer of dry sand taken from the sea-shore was spread evenly over it. Four sides were then provided which were designed in such a way that they formed the walls of a square that could be enlarged or diminished at will. Each side was made out of strips of tin 12 feet in length and was bent as in fig. I.

Fig. I.

The horizontal piece was 8 inches wide, the larger of the two verticals 6 inches high, and the smaller, one inch. At one end, the larger vertical plate extended beyond the rest of the side for 8 inches, so that it might overlap the horizontal part of the one joined to it at right angles. The four sides were placed upon the ground at right angles to each other, with the horizontal part flush with the ground and the smaller vertical pushed into the sand so as to prevent the fleas from crawling underneath

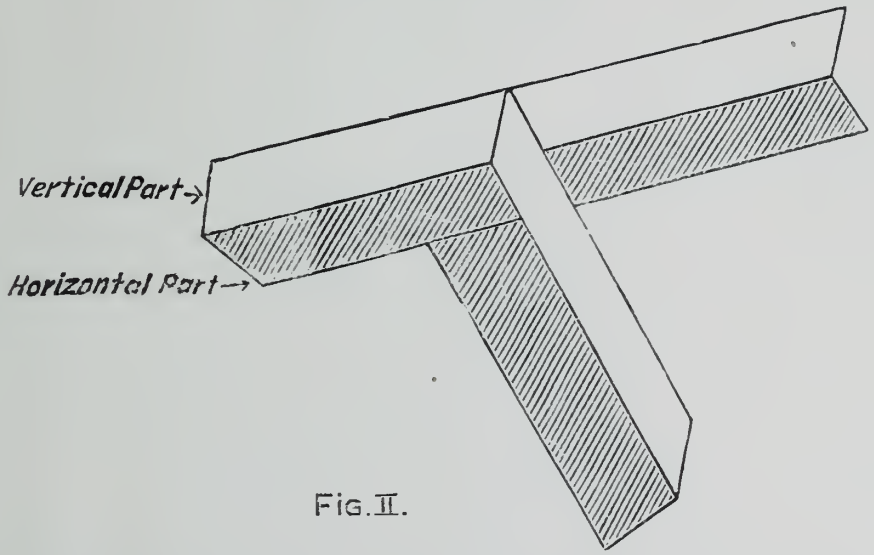


Fig. II.

At the angles of the square the horizontal part of one lay in close apposition to that of the one at right angles to it (Fig. II) and its projecting vertical part reached across the horizontal part and so joined closely with the vertical part of the other. The small gap between the two horizontals was covered over with a narrow strip of paper.

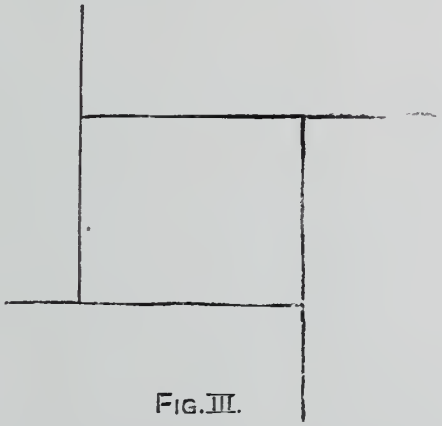


Fig. III.

The whole when spread out on the ground had the appearance seen in Fig. III and a square was obtained, the area of which could be altered and

which was surrounded by a flat tin surface 8 inches wide. This surface was covered with a mixture of white paint and resin just before any experiment was performed. The vertical part of the tin sides acted as a shelter which kept the sand outside the enclosure from blowing on to the paint when there was any wind.

The experiments were performed by making the square of such a size that the tin sides were a certain known distance away from the edge of the carpet. The rest of the technique was the same as that of the tray experiments. The carpet laid in the middle of the square was infested with fleas by sprinkling an equal number on both sides of it. The exposure was then made and at the end of an hour the sides of the tray were lifted, taken into the shade and the white paint searched for any fleas which might have jumped on to it. The presence of fleas on the paint proved that these insects were able to travel the distance between the edge of the carpet and the tins, and in the next experiment the distance between the two was increased. At the end of the experiment and before the removal of the tin walls four guineapigs were allowed to run about inside the square, but no fleas were ever found on them in any of the experiments. All experiments, with the exception of the first, which was a trial, were made at the time of day most likely to give a maximum temperature of about 120° Fah.

A control experiment was not performed with this series as it did not appear to be necessary. The experiments were carried out in two ways, in the first series (Ex. IV, part I, page 20) the sand on the square was kept in the shade until the experiment was prepared and was then exposed to the sun. In this way the method was tested under the most adverse circumstances, because the sand was quite cool and had to absorb the heat after the experiment had started, thus allowing the fleas to travel over a greater distance than they otherwise would have been able to do had the sand been exposed to the sun beforehand.

The second series (Ex. IV, part II, page 21) the square was prepared in exactly the same way as it would be in practice. The thermometers were placed on the surface of the sand in the early morning and were watched until they registered a temperature of 120°. The carpet was then prepared and placed in the centre of the square, and the rest of the experiment was carried out in a similar way to that which has already been described. In the first series of experiments (Table IV, page 20), it will be seen that the fleas were able to travel across four feet of sand before they were destroyed by the heat. In the other series (Table V, page 21), however, when the sand was previously heated, a distance of two feet was sufficient to destroy all the fleas.

These experiments demonstrated very clearly the way in which the fleas

always travel away from the sun. As the experiments were carried out in the early morning the bearing of the sun was always a few degrees south of east, and the fleas were always found in largest numbers on the western side of the square, and a few were seen on the northern border, while none were ever found on the east or south borders. Thus in one of these experiments 36 fleas were seen on the north, 67 on the west, none on the east and none on the south; and on several occasions the western border was the only one on which any fleas were discovered.

Part III.

Experiment with Resais (Cotton Quilts).

The experiments with the resais had unfortunately to be performed just before the monsoon broke in Bombay, with the result that many of the experiments were spoilt owing to the frequent overclouding of the sun during the exposures.

The experiments were performed on trays the floors of which were covered with sand, and are merely a repetition of several described in part I of the report. The resais were made of cotton cloth stuffed with cotton wool and measured 4 feet × 3 feet and were $1\frac{3}{4}$ inches thick.

In the first series of experiments (Ex. V, part I, page 22), the resais were not turned during the exposure, and it will be seen that in one or two cases the heat of the sun was unable to penetrate their whole thickness and reach the fleas on their under surface. To overcome this difficulty a second series of experiments (Ex. V, part II, page 23) was carried out in which both surfaces of the resai were exposed in turn to the sun, and the result obtained by this method was quite satisfactory, as no fleas could be found alive after any of the exposures.

It was suggested that the fleas might burrow into the substance of the resai and thus obtain shelter. In some of the experiments, therefore, a flap was cut on the upper surface and a thermometer and a small bag of fleas was placed half-way between the upper and lower surfaces in the middle of the cotton wool. At the end of the exposure the fleas were examined and were all found to be dead, while the temperature in the centre was always far in excess of the temperature in the sun; in one experiment reaching as high as 158° (Table VII, part II, page 23). The fleas on the surface of these resais were watched also to see if they made any at tempt to burrow into the cotton wool when they jumped on to it, but they never showed any inclination to do so.

We may, therefore, conclude that padded clothing and resais can also be disinfected by this method, but they must be turned over several times during the hour.

The experiments which have been described above show that the sun makes a very efficient disinfectant for flea-infested clothing, and that it is at once simple to use and free from expense. It may be of use, therefore, to draw up a series of rules which ought to be observed when clothes are to be disinfected by this method.

Rules for disinfection of clothing by exposure to the sun.

(1) The ground which is to be used for the purpose should be so chosen that the sun will be able to shine on it for the whole of each day. It should not be near any houses, trees, etc., which would be able to cast a shadow on it while it is in use.

(2) It should be flat and devoid of grass or stones, or anything which would afford shelter to the fleas.

(3) It should be entirely covered with a smooth layer of fine sand which should be at least 3 inches deep.

(4) The surface temperature of the sand must be at least 120° Fahrenheit (49° Centigrade) before the clothes are spread out upon it. If the ground is to be used every day for as long a period as possible the thermometer should be laid on the sand in the early morning, and as soon as it has reached 120° Fahrenheit the process of disinfection may be commenced. This may be carried on until the surface temperature falls below 120° F.

(5) The clothes should be spread evenly on the ground in a single layer, if possible.

(6) They should be left in the sun for one hour. Padded clothing, such as resais and thick coats, should be turned over once or twice during the exposure, so that each part of them may be directly exposed to the sun for some of the time.

(7) No clothes should be placed within 3 feet of the edges of the sand.

(8) The whole area should be fenced in so as to prevent animals straying over it while the process of disinfection is being carried out.

EXPERIMENT I.

To show the effect of the sun on flea-infested clothing when exposed to it on a hard surface, and to discover the time of exposure necessary to destroy all the fleas.

TABLE I.

No.	Date.	No. of fleas.	Time of exposure.	Minutes.	CONTROL—SHELTERED FROM SUN.			EXPERIMENT—EXPOSED TO SUN.			REMARKS.
					Fleas alive.		Fleas dead.	Fleas alive.		Fleas dead.	
					On guineapigs.	In trays.		On guineapigs.	In trays.		
1	8th December 1909.	100	12-20 to 12-30	10′	32	0	4	7	0	72	No clouds, but a good breeze.
2	11th January 1910 .	100	12-30 to 1-0	30′	21	22	9	1	4	38	No clouds and no breeze.
3	13th January 1910 .	100	12-0 to 12-45	45′	12	34	27	0	0	73	No clouds, no breeze.
4	14th January 1910 .	100	12-0 to 12-45	45′	37	23	11	0	0	70	No clouds, a good breeze.
5	12th January 1910 .	100	12-0 to 1-0	60′	19	33	20	0	0	46	No clouds, no breeze.

EXPERIMENT II.

To show the effect of the sun on flea-infested clothing when exposed to it—

(I) on sand, and
(II) on leaves and grass } for 45 minutes.

TABLE II.

No.	Date.	Fleas No.	Substance in tray.	Time of exposure.	Minutes.	CONTROL—SHELTERED FROM SUN.			EXPERIMENT—EXPOSED TO SUN.			REMARKS.
						Temperature F.		Result in 3 hours. Fleas on guineapigs.	Temperature F.		Result in 3 hours. Fleas on guineapigs.	
						Under carpet.	Over carpet.		Under carpet.	Over carpet.		
1	21st January 1910	100	½ inch sand	12-30 to 1-15	45′	—	—	34	130°	123°	0	No clouds, some breeze.
2	26th January 1910	100	1½ inches sand.	12-0 to 12-45	45′	—	87°	49	119°	118°	0	No clouds, some breeze.
3	27th January 1910	100	leaves and grass.	11-35 to 12-20	45′	94°	84°	4	117°	130°	1	No clouds, no breeze.
4	31st January 1910	100	leaves and grass.	12-0 to 12-45	45′	81°	94°	28	117°	142°	0	No clouds, no breeze.
5	1st February 1910	100	leaves and grass.	10-0 to 10-45	45′	75°	89°	47	103°	130°	27	No clouds, no breeze.

EXPERIMENT III.

To discover the minimum temperature required to kill fleas in clothing, when the clothes are exposed to the sun, on a sandy surface.

Table III.

No.	Date.	Fleas No.	Time of exposure.	Minutes.	Control—Sheltered from Sun.			Experiment—Expose to Sun.			Remarks.
					Temperature.		Fleas found alive.	Temperature.		Fleas found alive.	
					Under carpet.	Over carpet.		Under carpet.	Over carpet.		
1	8th February 1910 .	100	8-30 to 9-30	60′	76°	78°	66	91°	95°	47	Sun was five times overclouded. Numerous live fleas were seen in experimental tray.
2	9th February 1910 .	100	8-30 to 9-30	60′	74°	76°	64	89°	97°	44	No clouds and no breeze.
3	14th February 1910 .	100	9-30 to 10-30	60′	79°	80°	49	107°	105°	27	No clouds but cold breeze blowing. Numerous fleas seen alive in experimental tray.
4	10th February 1910 .	100	9-0 to 10-0	60′	76°	80°	41	103°	108°	4	No clouds and no breeze.
5	2nd February 1910 .	100	9-30 to 10-15	45′	84°	86°	41	115°	108°	21	
6	11th February 1910	100	9-15 to 10-15	60′	80·2°	85°	44	108°	112°	6	No clouds, no breeze.
7	16th February 1910 .	100	9-30 to 10-30	60′	82°	81°	43	114°	112°	7	No clouds, good breeze.
8	17th February 1910 .	100	9-45 to 10-45	60′	82°	85°	45	114°	116°	0	No clouds, no breeze.
9	26th January 1910 .	100	12-0 to 12-45	45′		87°	49	119°	118°	0	No clouds, some breeze.
10	15th February 1910 .	100	10-0 to 11-0	60′	87°	85°	41	121°	119°	0	No clouds, strong breeze.
11	7th February 1910 .	100	9-30 to 10-30	60′	86°	90°	47	123°	121°	0	
12	4th February 1910 .	100	12-15 to 12-30	45′	93°	99°	24	133°	122°	0	
13	21st January 1910 .	100	12-30 to 1-15	45′	...	...	34	130°	123°	0	No clouds, some breeze.
14	3rd February 1910 .	100	12-20 to 12-50	45′	92°	98°	26	128°	140°	0	

EXPERIMENT IV.

To discover the distance fleas are able to travel on a sandy surface when they have left clothes exposed to the sun.

I.—When the sand has been kept cool before the commencement of the experiment.

TABLE IV.

No.	Date.	Fleas No.	Distance in feet between edge of dhurrie and tin.	Time of exposure.	Temperature		Fleas found on borders.	Remarks.
					Under carpet.	Over carpet.		
1	29th March 1910 . .	300	0·5	11-50 to 12-50 . .	142°	139°	49	No fleas on guineapigs.
2	30th March 1910 . .	150	0·5	9-15 to 10-15 . .	112°	122°	94	Ditto.
3	31st March 1910 . .	150	0·5	9-45 to 10-45 . .	117°	125°	72	Ditto.
4	1st April 1910 . .	300	0·5	10-0 to 11-0 . .	120°	128	103	Ditto.
5	2nd April 1910 . .	300	0·5	10-0 to 11-0 . .	120°	125°	58	Ditto.
6	4th April 1910 . .	300	1·0	10-15 to 11-15 . .	126°	122°	52	Ditto.
7	5th April 1910 . .	300	1·5	10-15 to 11-15 . .	120°	130°	66	Ditto.
8	8th April 1910 . .	300	2·0	10-20 to 11-20 . .	126°	125°	57	Ditto.
9	9th April 1910 . .	300	2·5	10-15 to 11-15 . .	124°	128°	19	Ditto.
10	12th April 1910 . .	400	4·0	10-15 to 11-15 . .	125°	122°	62	Ditto.
11	13th April 1910 . .	300	5·0	10-15 to 11-15 . .	...	...	0	Ditto.
12	14th April 1910 . .	300	5·0	10-0 to 11-0 . .	134°	132°	0	Ditto.

EXPERIMENT IV—*contd.*

II.—When the sand has been previously heated to 120°.

TABLE V.

No.	Date.	Fleas No.	Distance in feet between edge of dhurrie and tin.	Time of exposure.	Sand temperature.		Carpet temperature at end of experiment.		Fleas caught on the borders.	REMARKS.
					Beginning of experiment.	End of experiment.	Under	Over		
1	15th April 1910	300	3	9-55 to 10-55	120°	134°	135°	134°	0	
2	16th April 1910	300	2	10-5 to 11-5	120°	130°	130°	130°	0	
3	19th April 1910	300	1	10-10 to 11-10	120°	127°	125°	122°	15	Sun was overclouded twice causing temperature to fall considerably in the middle of experiment.
4	20th April 1910	300	1	9-45 to 10-45	120°	134°	131°	136°	3	

EXPERIMENT V.

To find out if fleas in infested resais can be destroyed by exposing the latter to the sun.

I.—When the resais were not turned during the experiment.

TABLE VI.

Control temperature not taken. Resai not turned.

No.	Date.	Fleas No.	Time of exposure.	Hours.	Control—Fleas found alive.	Experiment.			Remarks.
						Temperature under.	Temperature over.	Fleas found alive.	
1	26th May 1910 . .	200	10-0 to 12-0	2	27	1st hour 115° 2nd hour 122°	122° 125°	6	Sun overclouded many times altering temperature.
2	27th May 1910 .	200	10-30 to 1-30	3	23	1st hour 110° 2nd hour 115° 3rd hour 118°	115° 120° 124°	1	Sun overclouded frequently.
3	30th May 1910 . .	200	9-30 to 10-30	1	27	123°	134°	0	Sun overclouded only once or twice.
4	30th May 1910 . .	100	2-30 to 3-30	1	24	124°	125°	10	Resai placed on sand when it reached 120°.

EXPERIMENT V—*contd.*

II.—When the resais were turned over when the time of exposure was half completed.

TABLE VII.

Resai turned at half time. Bag of fleas placed in middle of resai in all cases.

No.	Date.	Fleas No.	Time of exposure.	Control—Fleas found alive.	Experiment.			Remarks.
					Temperature at end of experiment.		Fleas found alive.	
					Under	Over		
1	31st May 1910 . .	120	9-45 to 10-45	29	...	...	0	Sun clouded over very frequently. Thermometers not acting.
2	1st June 1910 . .	120	10-15 to 11-15	17	107·4°	127°	0	Sun clouded over frequently. Temperature in centre of resai 158°.
3	31st May 1910 . .	100	1-15 to 2-15	19	125·6°	127	0	Sun overclouded frequently.
4	2nd June 1910 . .	120	10-15 to 11-15	18	114·8°	1364"	0	Sun overclouded at times. Temperature in centre of resai 143°·6.

APPENDIX.

Experiments made to devise a simple kind of thermometer which will always register 120°F.

While carrying out the experiments it occurred to us that a simple form of thermometer might be designed for this method of disinfection, by exposing to the sun a glass capsule containing a wax having a melting point of 120°F. An instrument of this sort would lessen expense by obviating the necessity for keeping a real thermometer, and would be much less likely to be broken by the class of people who would probably use it.

It was found that the ordinary vaseline in the laboratory when heated in a test-tube melted at 116°F. and that it required the addition of two parts hard paraffin (with a melting point of 138·2°F.) to every three parts vaseline to produce a mixture which melted at 120°F. Samples of this were put in small glass capsules, made from ordinary glass tubing, and were exposed to the sun with a thermometer beside them. The wax, however, showed no signs of melting till 122° was reached and was not entirely fluid till 125° was registered. It was apparent that this was due to the fact that the glass tubing delayed the transmission of the heat and that the proper wax would have to be discovered by direct experiment. A series of capsules were, therefore, made and were filled with samples of:—

(i) Pure vaseline.
(ii) Vaseline 3 parts, hard paraffin 1 part.
(iii) Vaseline 4 parts, olive oil 1 part.
(iv) Vaseline and olive oil equal parts.
(v) Vaseline 3 parts, olive oil 2 parts.

and a large number of exposures were made with these using a thermometer as a control. The results are embodied in Table VIII (page 26). There was a little difficulty in deciding the exact melting point of the wax, and two observations were, therefore, made on each occasion. The temperature was first noted when the wax showed distinct signs of being soft by sliding slowly up and down inside the capsule when the latter was tilted. The second observation was made when the wax had become altogether fluid and flowed up and down the tube quite easily. It will be seen that pure vaseline gave the best results for the purpose in view. All the other preparations were either too high or too low. The vaseline became soft almost always at 120°, and never at a lower temperature, and became fluid between 122° and 125°. It is safe to

say, therefore, that the softening of the vaseline would be a safe indication that the process of disinfection could be commenced.

Of course the temperature at which the vaseline would melt would differ somewhat according to the thickness of the glass tubing which contained it, and possibly also with the brand of vaseline used. The kind of tubing employed in the above experiments was that used for making Pasteur's pipettes, and any variation due to differences in size, etc., could easily be corrected by carrying out a few experiments similar to those described above.

TABLE VIII.

Date.	State of wax.	Vaseline, pure.	Vaseline 3 parts; Paraffin 1 part.	Vaseline 4; Olive oil 1.	Vaseline 2; Olive oil 2.	Vaseline 3; Olive oil 2.
13th April 1910	Soft	120°	122°	...	...	...
	Fluid	122°	125°	...	118°	...
14th April 1910	Soft	120°	125°	...	...	...
	Fluid	125°	127°	...	...	...
15th April 1910	Soft	120°	120°	114°	...	114°
	Fluid	122°	122°	116°	...	116°
16th April 1910	Soft	120°	122°	114°	...	114°
	Fluid	125°	126°	120°	...	117°
19th April 1910	Soft	125°	126°	120°	...	116°
	Fluid	127°	129°	122°	...	118°
20th April 1910	Soft	120°	122°	115°	...	114°
	Fluid	123°	125°	118°	...	118°
21st April 1910	Soft	120°	122°	115°	...	115°
	Fluid	122°	126°	120°	...	117°
27th April 1910	Soft	128°	125°	114°	...	115°
	Fluid	125°	127°	118°	...	120°
28th April 1910	Soft	121°	122°	114°	...	114°
	Fluid	123°	127°	119°	...	118°
29th April 1910	Soft	122°	125°	116°	...	114°
	Fluid	125°	127°	120°	...	117°

TABLE VIII—*contd.*

Date.	State of wax.	Vaseline, pure.	Vaseline 3 parts; Vaseline 2 parts.	Vaseline 4; Olive oil 1.	Vaseline 2; Olive oil 2.	Vaseline 3; Olive oil 2.
30th April 1910 .	Soft . .	122°	123°	114°	...	115°
	Fluid .	126°	125°	118°	...	117°
3rd May 1910 . .	Soft . .	123°	124°	114°	...	114°
	Fluid .	125°	127°	116°	...	118°
4th May 1910 . .	Soft . .	121°	122°	114°	...	114°
	Fluid .	124°	124°	117°	...	116°
5th May 1910 . .	Soft . .	120°	122°	114°	...	115°
	Fluid .	123°	125°	118°	...	117°

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET

No 40.

(*NEW SERIES*)

SCIENTIFIC MEMOIRS

BY

OFFICERS OF THE MEDICAL AND SANITARY EPARTMENTS

OF THE

GOVERNMENT OF INDIA

THE DESTRUCTION OF FLEAS BY EXPOSURE TO THE SUN.

BY

CAPTAIN J. CUNNINGHAM, M.D., I.M.S.

Offg. Assistant to the Director, Bombay Bacteriological Laboratory

---

ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA
BY THE SANITARY COMMISSIONER WITH THE GOVERNMENT
OF INDIA.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1911

Price annas 8 or 9d.